CHAPTER

2

Overview of Water Resources

2.1 INTRODUCTION

2.1.1 Geography

The Prescott Active Management Area (AMA) encompasses 485 square miles in Yavapai County in central Arizona. It lies within the Central Highlands physiographic province and is typified by gently rolling topography with broad sloping alluvial basins and fault block mountains. Elevations range from about 4,400 feet above sea level in the valleys to about 7,800 feet above mean sea level in the Bradshaw Mountains. Native vegetation varies from high desert grassland in the basin areas to coniferous forest in the surrounding mountains.

The AMA consists of two subbasins, the Little Chino and the Upper Agua Fria, which are bisected by a surface drainage divide. Granite Creek and Willow Creek comprise the major tributaries which drain the Little Chino Subbasin into the Verde River. Lynx Creek and the Agua Fria River drain the Upper Agua Fria Subbasin into the Agua Fria River. With the exception of small perennial stretches at Del Rio Springs and along a small reach of the Agua Fria River in the vicinity of Humboldt-Dewey, all surface drainages in the Prescott AMA are either ephemeral or intermittent. The Little Chino Subbasin encompasses the northwestern half of the AMA, while the Upper Agua Fria Subbasin spans the southeastern half of the AMA.

2.1.2 Climate

The Arizona Department of Water Resources (Department) reviewed historical precipitation data for the Prescott AMA using a 99-year period (1899-1997) of records obtained from the Prescott precipitation gage. This analysis produced a 99-year average annual precipitation of about 19.39 inches per year, with a median of 19.57 inches per year. On an annual basis, however, precipitation has varied considerably. A short-term average, taken from 1982-1993 records, reflected a wetter climatic cycle averaging about 20.9 inches of precipitation per year. Records for 1994 through 1997, however, show a drier cycle, averaging 15.39 inches per year. The summer rainfall season, ranging from May to September, produced a long-term average rainfall of about 9 inches. Most of this seasonal rainfall typically occurs during the height of the monsoon season (June-August), where long-term rainfall averaged about 7 inches per year. Significant precipitation also results from winter storm events that often develop across northern and central portions of Arizona, although the frequency and intensity of these storms vary substantially year to year.

Prolonged drought conditions have been experienced throughout much of Arizona, including the Prescott AMA, since 1995. El Niño related precipitation created an exception to these drought conditions in the winter of 1997-1998. It is unclear whether recent conditions are an indication of a long-term drought cycle or a brief pause in what has generally been considered a wet climatic cycle over the last few decades. In either case, a continuation of drought conditions could impede efforts to provide a safe and secure supply of water to the water users of the Prescott AMA.

Average annual precipitation around Chino Valley is somewhat lower than it is around Prescott, according to recent records. From 1982 to 1993 an average of about 10.41 inches of annual precipitation was received in Chino Valley, based on the precipitation gage at that location. Lower rainfall volumes could partially be attributed to the area's greater distance from the mountain ranges immediately adjacent to the City of Prescott and the lower elevation at Chino Valley. These data suggest that annual precipitation levels are not uniform throughout the Prescott AMA.

2.2 DATA SOURCES

In the early to mid 1990s water levels were rising in some areas and some formerly dry springs were running again. At the time it could not be determined whether these conditions were the result of a return to safe-yield or a temporary response to major recharge events in 1993 and to a lesser extent in 1995, coupled with reduction in agricultural pumping.

During the development phase of the Assured Water Supply Rules (AWS Rules), the Department did not possess enough hydrologic data or tools to conclusively determine whether the Prescott AMA was at safe-yield. Therefore, the Department resolved to expand its hydrologic knowledge of the Prescott AMA to allow an accurate determination of the AMA's safe-yield status to be made. As a result of additional data collection and completion of a hydrologic computer model, many of the previously held assumptions about long-term groundwater conditions in the Prescott AMA have changed. The conditions in the early 1990s were demonstrated to be primarily a result of 1993 recharge and reduction in agricultural pumping. In fact, the Department has determined that Prescott has never been in safe-yield since the AWS Rules were adopted.

2.2.1 Arizona Department of Water Resources Basic Data

Water level measurements have been collected for many years from a number of wells in the Prescott AMA, including a few since the 1930s and 1940s. In 1995, the Department's Hydrology Division and the Prescott AMA jointly designed improvements to the existing water monitoring program in the Prescott AMA. Figure 2-1 shows the monitoring locations existing in 1995. Figure 2-2 shows the expanded network in place in 1997. A line of about 17 or 18 wells was expanded in 1997 to include 57 index wells and five surface water monitoring gages. A cooperative effort between the Department, the City of Prescott, and Yavapai County is underway to further expand this monitoring program.

Data obtained from the expanded monitoring program were incorporated into the 1998 calendar year annual data report and the director's determination that the Prescott AMA is no longer at safe-yield.

2.2.2 Arizona Department of Water Resources Computer Model

Over the years, the Prescott AMA has been studied by a number of researchers and scientific organizations. In 1995, the Department completed an extensive hydrogeological study of the Prescott AMA which resulted in the development of a groundwater flow model of the regional aquifer system of the Little Chino and Upper Agua Fria Subbasins. The period of time simulated by the groundwater flow model includes the predevelopment period (circa 1940), as well as the period of groundwater exploitation and development from 1940 to 1993. This groundwater flow model provides the Prescott AMA with a valuable tool to analyze hydrologic conditions and to conduct long-range planning. A key advantage of the model over simply relying on water level measurements is the ability of the model to replicate natural phenomena, normalize conditions, and account for such factors as changes in agricultural activity and actual locations of pumping. The groundwater flow model has been an important component in the determination that the Prescott AMA is no longer at safe-yield.

The data included in this model are extensive. Historic water level changes, as discussed in the previous section, were examined. Pumpage data were collected. Groundwater discharges from riparian areas, springs, and streams were analyzed and quantified. Groundwater underflow leaving the Little Chino Subbasin was estimated. Natural recharge along mountain fronts and along stream channels was estimated. Artificial recharge from the City of Prescott's airport recharge facility was tabulated. Groundwater budgets were prepared from the assembled data and used as inputs to the groundwater flow model. The results of the hydrogeologic study and calibration of the groundwater flow model have indicated that the Prescott AMA is no longer in a safe-yield condition.

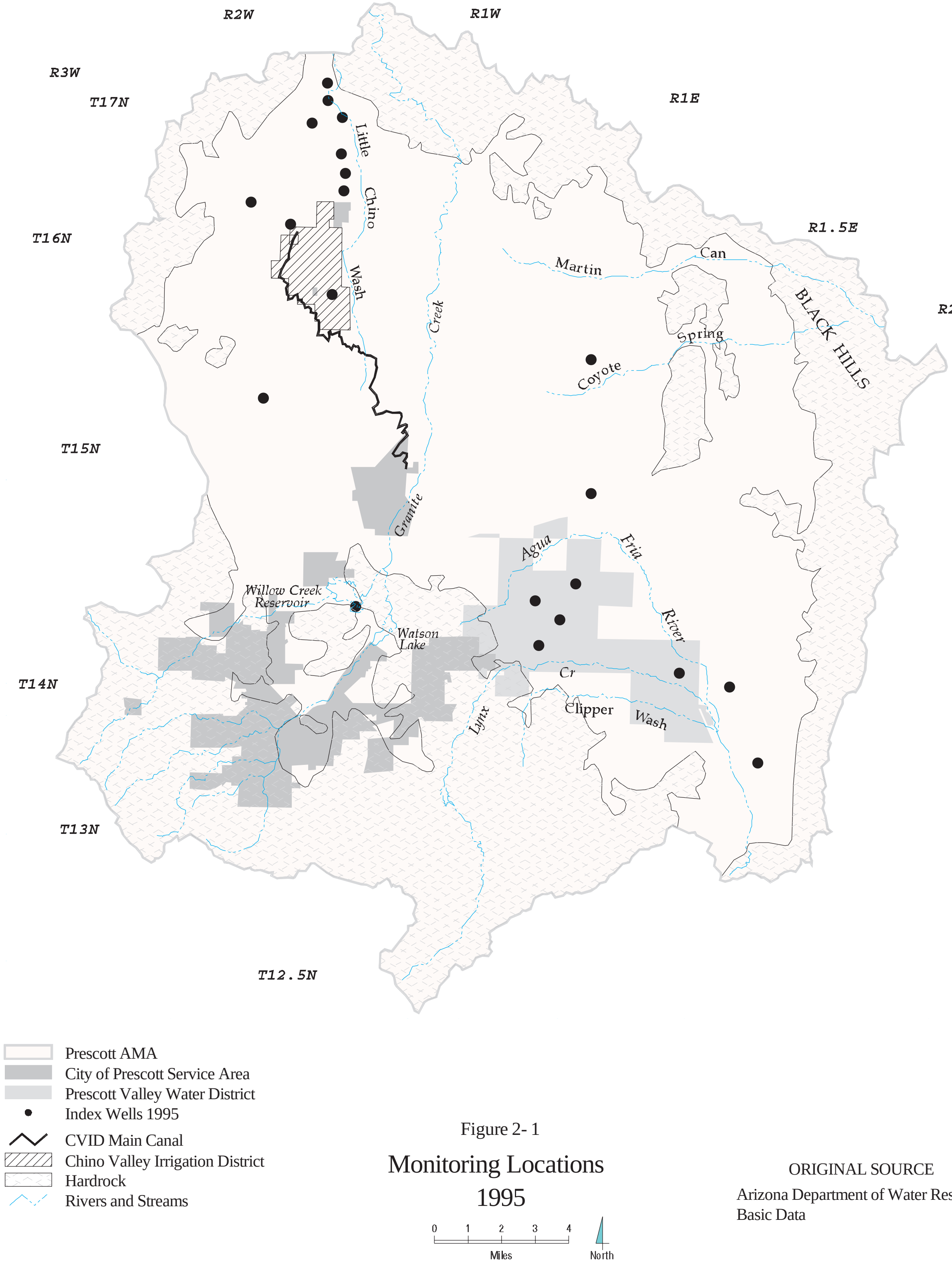


Figure 2- 1

Monitoring Locations
1995

ORIGINAL SOURCE
Arizona Department of Water Resources
Basic Data

PRESCOTT AMA

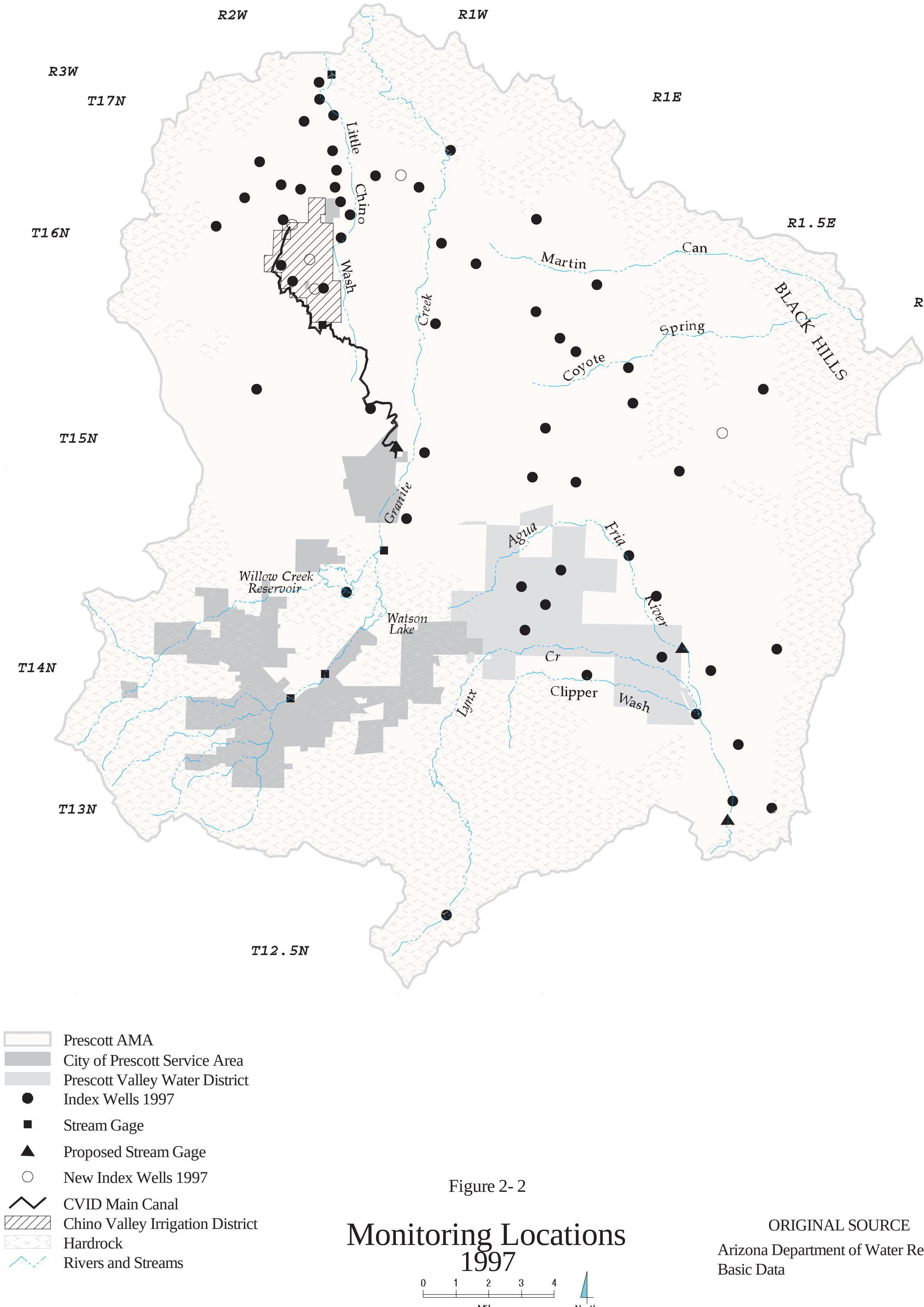


Figure 2- 2

Monitoring Locations 1997

ORIGINAL SOURCE
Arizona Department of Water Resources
Basic Data

The model inputs were subjected to an extensive sensitivity analysis which examined the model's change in response to variations in many of the input data. The sensitivity analysis included an examination of the change in the model's response to significant increases or decreases in mountain front recharge and flood recharge. The results of the sensitivity analysis indicated that the current model input estimates are reasonable and that it is unlikely that long-term natural recharge or flood recharge has been underestimated.

In addition to examining the safe-yield status of the Prescott AMA, the groundwater model will be updated and used to project future groundwater conditions based on assumptions about future water supplies and demands. Some potential supply and demand conditions to study include:

- retirement of agricultural lands
- purchase of Chino Valley Irrigation District (CVID) surface water rights by Prescott
- availability, use, and recharge of effluent including effects of different recharge locations
- the rate and degree of development within the Little Chino and Upper Agua Fria Subbasins
- use of Del Rio Springs surface water supplies to offset some current groundwater uses
- importation of Big Chino groundwater supplies
- locations of new wells and changes in pumping patterns
- potential impacts on exempt wells due to water level declines

Results of model projections will provide information on future conditions which can be used by groundwater managers, local governments, planners, and developers in making wise decisions to provide for future water needs in the Prescott AMA.

2.2.3 <u>Other Agencies and Reports</u>

2.2.3.1 Water Protection Fund Study

During 1997, a group of geologists from Arizona State University completed a stable isotope investigation of groundwater and surface water interaction in the Verde River headwaters area which encompasses considerable portions of the Big Chino Subbasin in the vicinity of the community of Paulden. Funded through a grant from the Arizona Water Protection Fund, the scientific team obtained stable isotope data, well log data, and streamflow measurements for the Verde headwaters area, with assistance from the Department.

Although the formula for water is normally given as H_20, an isotopic investigation seeks to identify the different types of hydrogen and oxygen atoms that are collectively referred to as "isotopes" (Knauth and Greenbie, 1997). There is also considerable isotopic variation depending on the location, depth, and age of water molecules within an aquifer. The Arizona State University isotopic study focused on identifying possible source aquifers which supply groundwater to the Verde River in the headwaters region below the confluence of the Verde River and Granite Creek.

Based on the interpretation of the isotope data, the authors arrived at several conclusions. One conclusion was that the "source" of the Verde River baseflow below the confluence with Granite Creek was mainly water leaking out of the Black Mesa aquifer. The isotope data also led the authors to conclude that groundwater from the upper and middle Big Chino Valley, the Little Chino Valley, and the Sullivan Lake area did not appear to be discharging into the Verde River (at least in the study area covered by the isotope survey).

It is important to state that the Department also recognizes that there is hydrogeologic data which indicate that there must be some degree of hydrologic connection between the Big Chino aquifer system and the

Verde River surface water drainage. It is believed that future hydrogeologic studies in the area will help integrate the available data and clarify the current differences in interpretation.

2.2.3.2 Privately Contracted Studies

The Shamrock Water Company contracted with a private hydrologic consultant to review the groundwater model developed by the Department. This study was commissioned in response to concerns of Shamrock Water Company about the declaration of groundwater mining within the Prescott AMA. Although this study identified areas where data were lacking and produced additional hydrologic findings, the Department concluded that the study did not significantly change the Department's groundwater model conclusions for the Prescott AMA.

2.3 SURFACE WATER CONDITIONS

The surface water system in the Prescott AMA is characterized by numerous ephemeral streams that carry snow melt and rainfall from the mountains that surround the Prescott AMA. Much of the ephemeral streamflow which reaches the basins of the Prescott AMA infiltrates and recharges the underlying groundwater system before exiting the basins. However, some streamflow does exit the Prescott AMA under high runoff conditions.

Granite Creek, Willow Creek, Little Chino Creek, Lonesome Valley Draw, and Big Draw are the primary ephemeral streams which drain the mountains of the Little Chino Subbasin. Granite and Willow Creek drain the southwestern portion of the Prescott AMA. Dams were constructed on both Granite Creek and Willow Creek, forming Watson Lake and Willow Lake respectively, to impound water for diversion to the CVID. During periods of prolonged flooding, flows from these lakes join at the confluence of Granite and Willow Creeks and then flow northward to join the Verde River several miles southeast of Paulden. Little Chino Creek and Big Draw drain the northwestern part of the Little Chino Subbasin. Little Chino Creek drains the CVID area and flows into the Del Rio Springs area where the surface and groundwater systems are interconnected. In this area, spring discharge provides essentially permanent baseflow conditions below the springs. Lonesome Valley Draw drains the eastern half of the Little Chino Subbasin.

2.4 GEOLOGIC AND AQUIFER CHARACTERISTICS

The Little Chino Subbasin comprises the northwestern portion and the Upper Agua Fria Subbasin comprises the southeastern portion of the Prescott AMA. The geologic structure of these subbasins is characterized by a deep structural trough which extends north-northwest for a distance of about 25 miles from near Humboldt in the southern part of the Upper Agua Fria Subbasin to near Del Rio Springs in the northern part of the Little Chino Subbasin. The trough was likely formed due to basin-and-range faulting and warping in both subbasins, which gradually filled with alluvial, sedimentary, and volcanic rocks.

The wide variety of rocks which fill the groundwater subbasins and form the surrounding mountains of the Prescott AMA have been grouped into three hydrogeologic units, geologic cross-sections of which are displayed in Figure 2-3. From oldest to youngest, the units are the Basement Unit, the Lower Volcanic Unit, and the Upper Alluvial Unit.

2.4.1 The Basement Unit

The Basement Unit is composed of a variety of igneous and metamorphic rocks that are generally dense, non-porous, and nearly impermeable (Wilson, 1988). It forms the impermeable floor and sides of the subbasins and is exposed at the land surface throughout the mountainous areas which surround the subbasins. There are a large number of domestic wells which tap into fissures and cracks in the Basement Unit. However, the Basement Unit has very limited groundwater storage and production capacity, being a hardrock area, and, because yields are small, is not regarded as an aquifer for other than domestic purposes. Within the Little Chino Subbasin, the Basement Unit generally underlies the Lower Volcanic Unit, and underlies the Upper Alluvial Unit in the Upper Agua Fria Subbasin.

2.4.2 The Lower Volcanic Unit

The Lower Volcanic Unit overlies the Basement Unit in most of the Little Chino Subbasin. It is composed of a thick sequence of basaltic and andesitic lava flows which are interbedded with layers of pyroclastic and alluvial material. The Lower Volcanic Unit, sometimes referred to as the basalt aquifer or layer, forms a highly productive confined (artesian) aquifer as determined from well logs in the northwestern portion of the Little Chino Subbasin. Many high-capacity irrigation wells (1,000-3,000 gallons per minute) tap into this aquifer system. Some of these high-capacity wells are included in the Prescott municipal well field, while a number are used for agricultural irrigation in and around the CVID.

The areal extent of the Lower Volcanic Unit is not well known in many other parts of the AMA. However, a high capacity production well has recently been drilled into volcanic deposits located near the City of Prescott airport recharge facility. Productive volcanic deposits have also been penetrated by some wells drilled in the Lonesome Valley and Prescott Valley areas. The total thickness of the Lower Volcanic Unit also is not well known, except at a few locations where wells have been drilled through the unit's entire thickness. The productive thickness of the Lower Volcanic Unit is estimated to range from less than 100 feet up to several hundred feet. These estimates are based on the average depth-of-penetration of wells that tap water from the Lower Volcanic Unit and from depth-to-bedrock maps produced from gravity data (Oppenheimer and Sumner, 1980).

Although the thick sequence of fine-grained materials which overlie the Lower Volcanic Unit tend to restrict the vertical movement of groundwater, groundwater flow does occur through cracks or fractures in these volcanic deposits. Natural recharge to the Lower Volcanic Unit aquifer occurs mainly through infiltration of runoff in ephemeral stream channels and along the mountain fronts of the Little Chino Subbasin. In unconfined areas, where the overlying Upper Alluvial Unit aquifer is unsaturated, recharge may directly reach the water table through deep percolation. In outlying areas, where the Upper Alluvial Unit aquifer is saturated and confining layers do not exist, recharge may reach the Lower Volcanic Unit aquifer through vertical groundwater flow. In other small areas where there are basalt outcrops, precipitation may move downward through openings and crevices to reach the Lower Volcanic Unit aquifer (Schwalen, 1967). Other sources of recharge to the Lower Volcanic Unit aquifer include incidental recharge from irrigation, canal seepage, and Prescott's artificial recharge project in the southwestern portion of the Little Chino Subbasin.

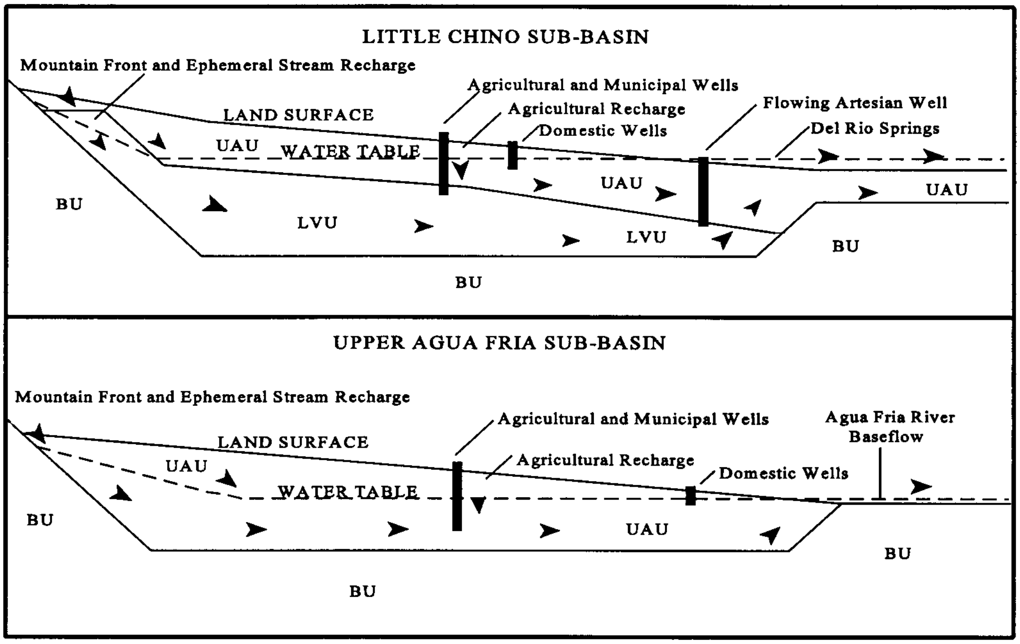
Natural discharge from the Lower Volcanic Unit occurs at two locations in the Little Chino Subbasin. Near Del Rio Springs, the hydraulic head or pressure in the Lower Volcanic Unit is greater than the head in the Upper Alluvial Unit. In this vicinity, groundwater flows upward from the Lower Volcanic Unit to eventually become springflow in the Del Rio Springs. Minor groundwater underflow may also leave the Prescott AMA through the bedrock gap just northwest of Del Rio Springs.

2.4.3 The Upper Alluvial Unit

Thick, saturated, sedimentary, and volcanic rocks fill the deep structural trough which extends northwest-southeast across the entire length of the Little Chino and Upper Agua Fria Subbasins. These rocks are collectively referred to as the Upper Alluvial Unit. The Upper Alluvial Unit constitutes the main, unconfined aquifer in the Prescott AMA.

Natural recharge to the Upper Alluvial Unit is derived from the infiltration of runoff in ephemeral stream channels and along the mountain fronts of the Prescott AMA. Agricultural irrigation and canal seepage

FIGURE 2-3
SUBBASIN HYDROLOGY
PRESCOTT ACTIVE MANAGEMENT AREA



Arrows represent direction of groundwater flow.

incidentally recharge the Upper Alluvial Unit. Artificial recharge of effluent at the City of Prescott's airport recharge site is another source of replenishment to the aquifer.

Production capacities vary substantially for wells in the Upper Alluvial Unit. In many instances, the yields are governed more by pump size than the aquifer's ability to produce water (Remick, 1983). In the Little Chino Subbasin, the Upper Alluvial Unit has been tapped mainly by numerous small-capacity domestic wells with less than 35 gallons-per-minute (gpm) capacity. In the Upper Agua Fria Subbasin, in addition to shallow domestic wells, large agricultural and municipal wells with pump capacities ranging from 100 to 3,000 gpm also tap into this aquifer (Wilson, 1988; Wellendorf, 1994).

Natural discharge from the Upper Alluvial Unit occurs at three locations in the Prescott AMA. In the Little Chino Subbasin, natural discharge occurs as spring flow at Del Rio Springs and as underflow through a bedrock gap located immediately to the northwest of Del Rio Springs. In the Upper Agua Fria Subbasin, natural discharge occurs as perennial baseflow along the Agua Fria River near Humboldt.

2.5 GROUNDWATER CONDITIONS

This section is meant to provide a brief synopsis of the groundwater conditions in the Prescott AMA along with a recent update derived from hydrologic data.

2.5.1 Water Level Maps

The Department uses a variety of hydrologic maps in the development of hydrologic groundwater models. To assist Prescott AMA water management efforts, hydrologic maps included in this report contain information about water level elevations, water level changes, and depth-to-water. Together, these maps provide useful information about past and present groundwater conditions in the Prescott AMA.

Water level elevation maps show the elevation of the water table above mean sea level. The general direction of groundwater flow in an aquifer is indicated by the orientation of the contours on a water level elevation map. A general rule of thumb to use when interpreting these maps is that groundwater flows from higher elevations to lower elevations, and the direction of flow is generally at right angles to the water level elevation contours. Figure 2-4 depicts Prescott AMA water level elevations from 1940, while Figure 2-5 displays water level elevations in 1994.

Water level change maps show the change in elevation of the water table over a specified period of time. Water level change maps are useful in identifying long-term and short-term changes in groundwater storage conditions in an aquifer. Figure 2-6 shows water level changes experienced in the Prescott AMA from 1940-1981 and Figure 2-7 depicts changes from 1982-1998. Figure 2-8 displays long-term changes between 1940 and 1994. Changes over time reflect differences between groundwater withdrawals and recharge to the aquifer. Figure 2-10 displays water level changes between 1994 and 1998.

Depth-to-water maps show the depth of the water table below land surface. However, the direction of groundwater flow is not necessarily determinable from depth-to-water maps. Depth-to-water maps provide information which is often used for well design and hydrologic interpretation purposes. A depth-to-water map depicting 1994 conditions in the Prescott AMA is provided in Figure 2-9.

2.5.2 Historic and Current Water Use Conditions

Irrigation historically has been the principal use of groundwater in the Prescott area. The first well to tap an artesian aquifer in the Little Chino Subbasin was drilled by the Chino Valley Auxiliary Water Users Association, a group of local farmers, in about 1927. The first flowing artesian well was drilled in 1930 by the Chino Valley Artesian Well Company, a group of local farmers interested in locating an artesian supply (Schwalen, 1967). Groundwater pumping for irrigation purposes in the Upper Agua Fria Subbasin may have occurred as early as 1936 (Wigal, 1988).

Use of groundwater for irrigation in the Little Chino Subbasin continued to increase from the 1940s to the 1970s, resulting in significant water level declines (Corkhill and Mason, 1995). Concerns over these declines caused portions of the area to be included by the state as part of the Granite Creek Critical Groundwater Area in the 1970s. When the Groundwater Management Act was adopted in 1980, water level measurements in the Prescott area indicated continuing groundwater declines. Thus, the legislature created the Prescott Active Management Area, which includes both the Little Chino and the Upper Agua Fria Subbasins.

Agricultural groundwater demands began to diminish during the late 1970s and early 1980s, partly contributing to the apparent stabilization of groundwater levels in many observation wells (Corkhill and Mason, 1995). Additionally, in the late 1980s and early 1990s, resumed year-round flow was observed in some of the originally flowing artesian wells located to the north of the Town of Chino Valley, a condition that had not occurred since the initiation of significant groundwater pumping for agricultural use. During this same period, population increases in the AMA were moderate. These occurrences and observations led some to conclude that the AMA was at or near a safe-yield condition for groundwater during the late 1980s and early 1990s.

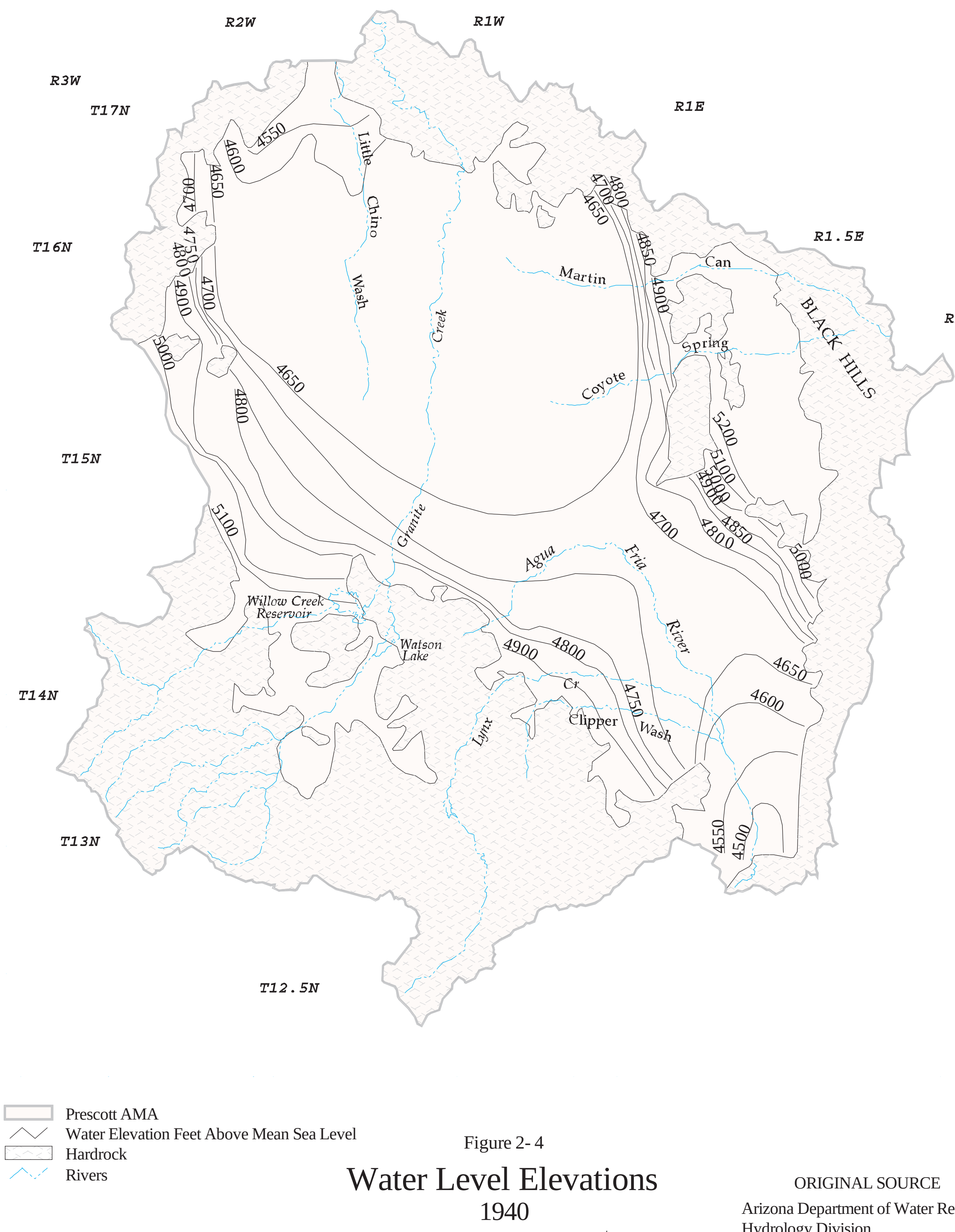


Figure 2- 4

Water Level Elevations

1940

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

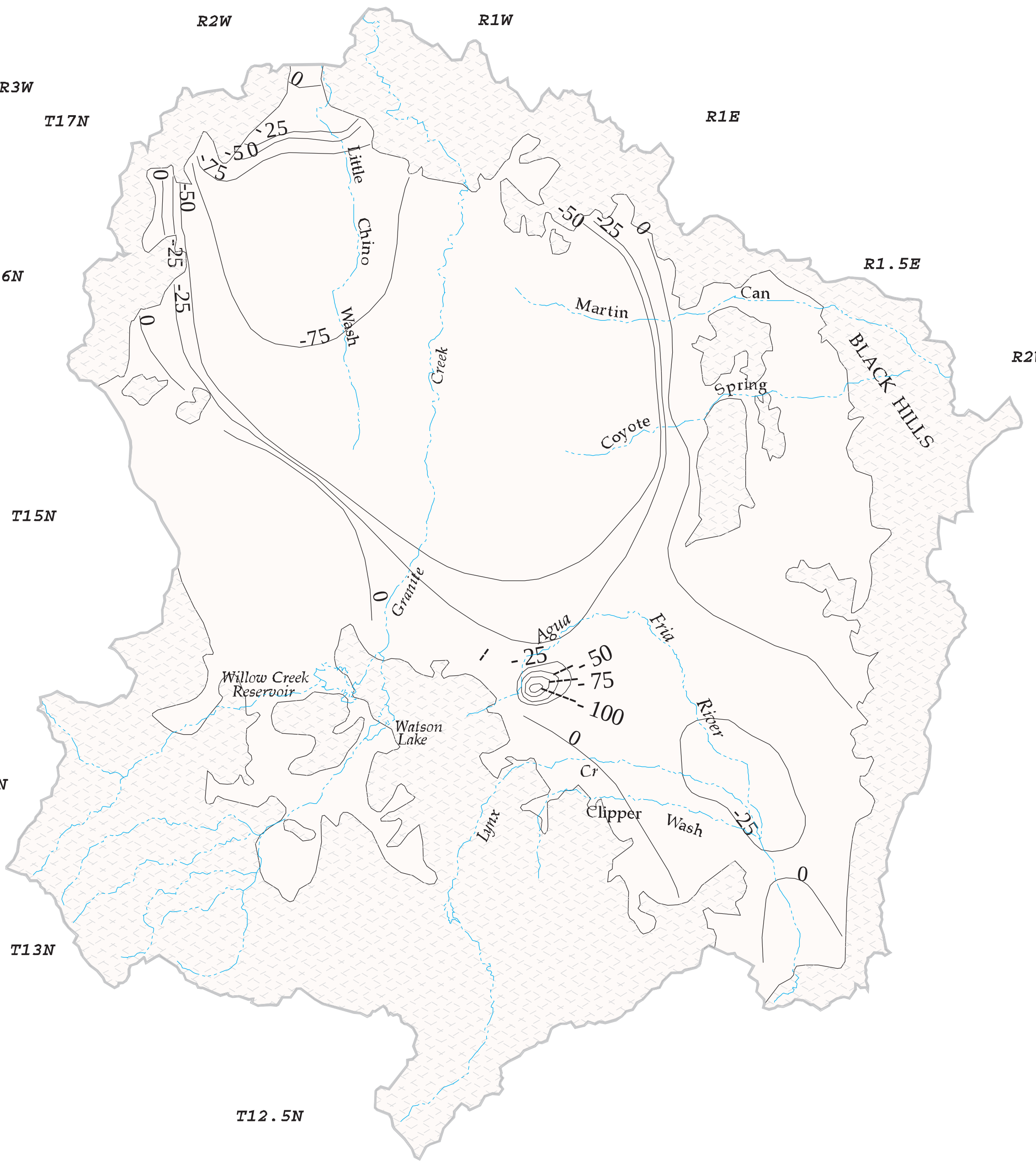
Figure 2- 5

Water Level Elevations

1994

ORIGINAL SOURCE

Arizona Department of Water Resources
Hydrology Division



Prescott AMA
Water Elevation Change in Feet
Hardrock
Rivers

Figure 2- 6

Water Level Changes

1940 - 1981

0 1 2 3 4
Miles
North

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

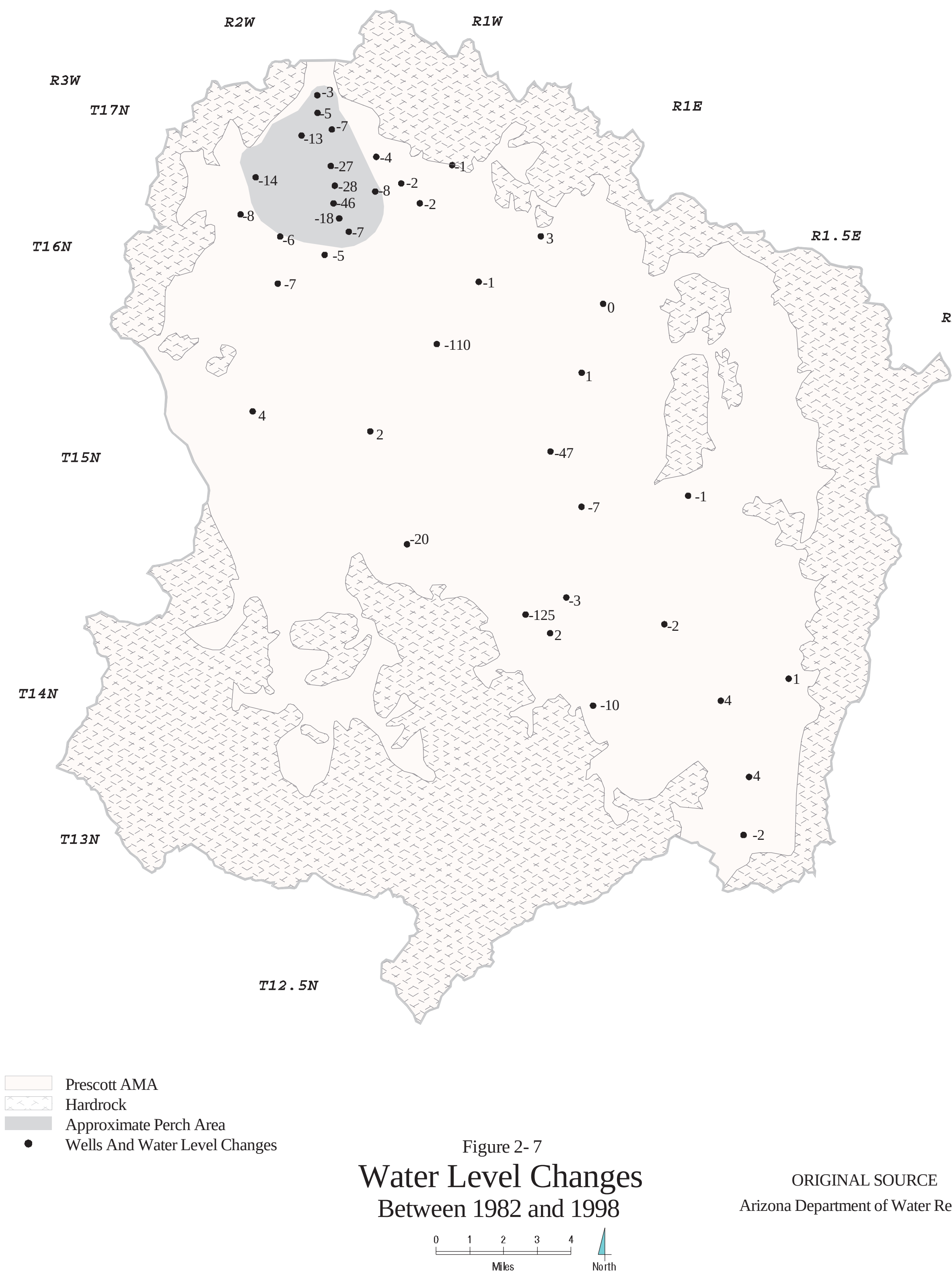


Figure 2- 7

Water Level Changes

Between 1982 and 1998

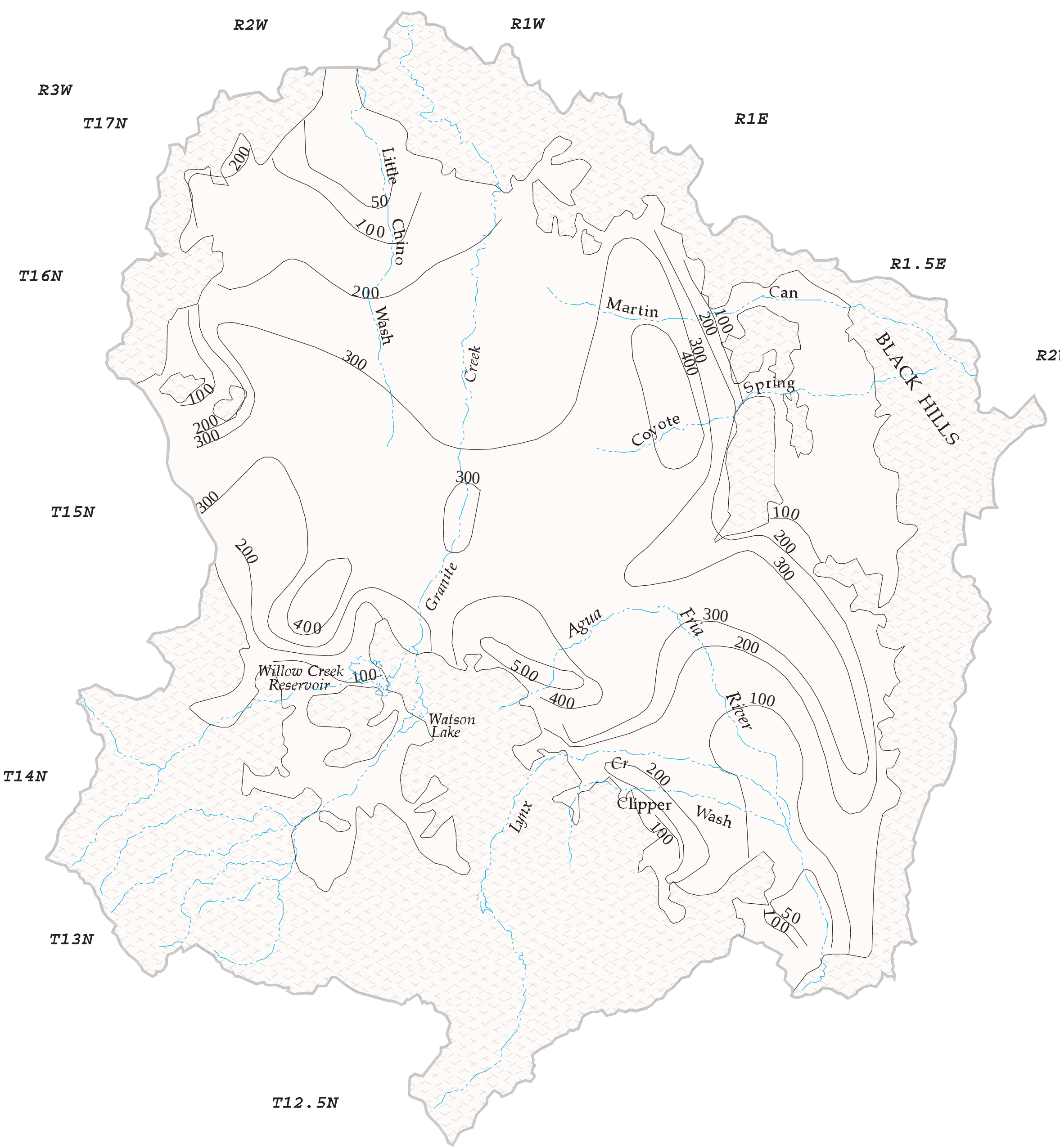
ORIGINAL SOURCE
Arizona Department of Water Resources

Figure 2- 8

Water Level Changes Between 1940 - 1994

- Prescott AMA
- Water Elevation Changes in Feet
- Inferred Water Elevation Changes in Feet
- Hardrock
- Rivers

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division



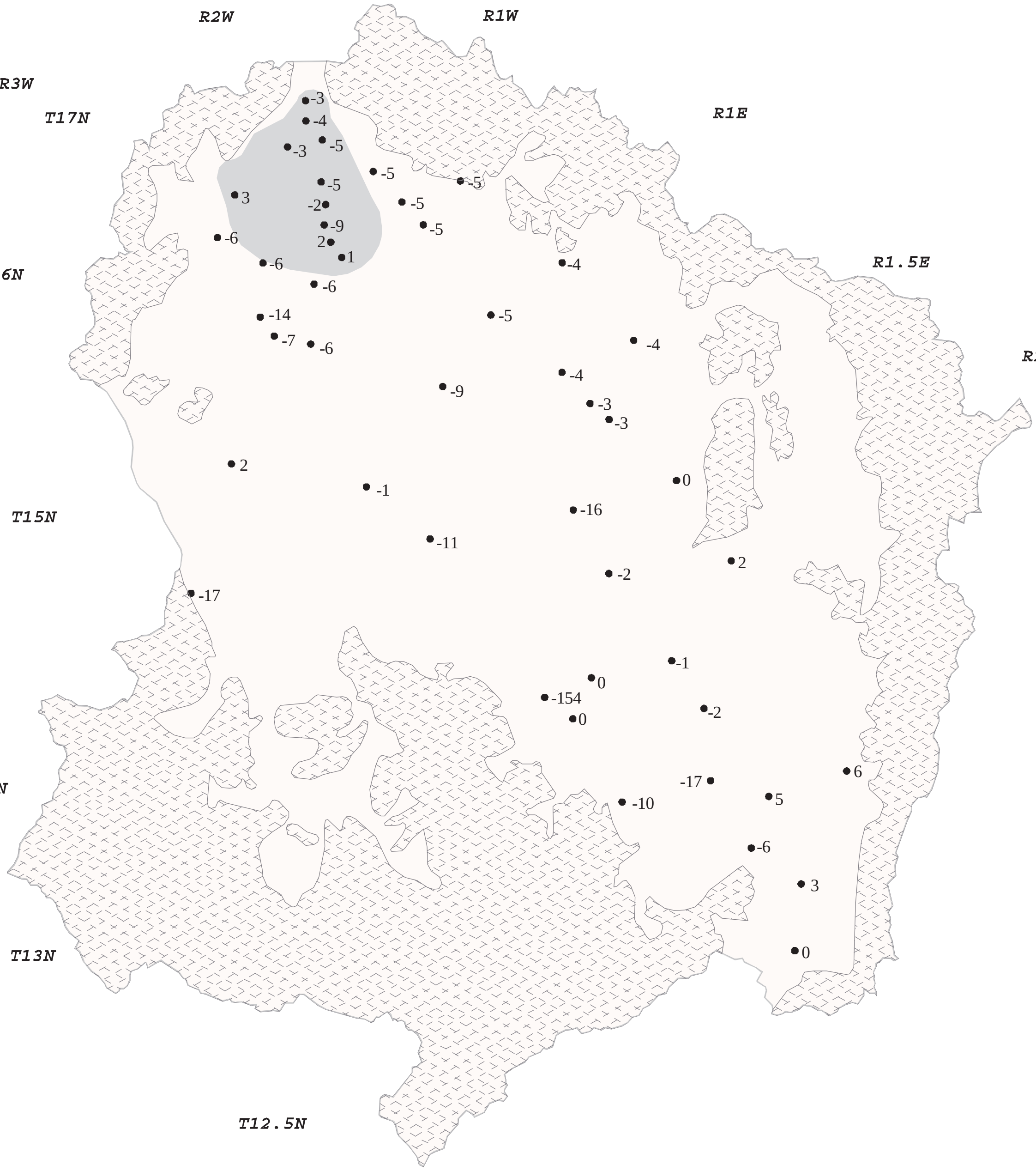
Prescott AMA
Depth to Water Feet Below Land Surface
Hardrock
Rivers

Figure 2- 9

Depth to Water
1994

0 1 2 3 4
Miles
North

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

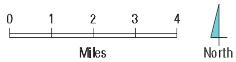


Prescott AMA Boundary
Hardrock
Approximate Perch Area
● Wells And Water Level Changes

Figure 2- 10

Water Level Changes

Between 1994 and 1998



ORIGINAL SOURCE
Arizona Department of Water Resources

The Prescott AMA is subject to short-term increases and decreases in water levels caused by variations of precipitation in the area. A one or two year dry cycle can cause water levels to drop noticeably; one or two years of wet weather can cause the opposite to occur. It is very important, therefore, to be able to distinguish between short-term and long-term trends in water level changes in the area.

During the early 1990s, the Department was developing the AWS Rules and analyzing whether the Prescott AMA was at safe-yield. At that time, some observers believed that the stabilizations in water levels that were occurring in the AMA were a short-term adjustment caused either by the above-average precipitation then occurring in the area or the decrease in pumping from the high levels of the 1960s and 1970s. Others believed that the improvement in groundwater level conditions during that time was due to the AMA having moved into a safe-yield condition. At the time the AWS Rules were developed, there was no clear evidence proving one theory over the other. Therefore, the Department believed that, without clear evidence, it would be premature to declare the AMA not at safe-yield and to implement significant restrictions on groundwater use for new subdivisions.

In 1995, the Department completed work on a computerized hydrologic model. This tool utilized a simulation of historic and current groundwater pumping and groundwater flow to replicate long-term trends in groundwater storage and water levels in the Prescott AMA (Corkhill and Mason, 1995). The model demonstrates that the AMA has been in a groundwater mining condition for a number of years. In fact, the observations of water level stabilization in the late 1980s and early 1990s were simulated with a high degree of precision by the groundwater flow model, even with an "overdraft" water budget as an input. Estimates of long-term recharge and discharge corroborated by the model allowed the construction of water budgets for previous and current periods. These water budget analyses, discussed in Chapter 3, clearly indicate that the AMA could not possibly be in a long-term "safe-yield" situation.

These factors support the hypothesis that the stabilization of water level declines during the late 1970s and 1980s was a reflection of the groundwater system's adjustment to both a new decreased pumpage regime associated with the retirement of agricultural acreage and the temporary availability of increased natural recharge from flood flows in 1978, 1980, 1983, and 1993 (Corkhill and Mason, 1995). The completion of the groundwater model and the evidence the model provided of ongoing mining conditions have clarified for the Department that the AMA was, in fact, not in a safe-yield condition in 1995.

Recent groundwater use history in the Prescott AMA has been characterized by a stabilization in the use of groundwater by agriculture and an increase in use by the municipal and industrial sectors. Groundwater use for irrigation peaked in the 1960s, diminished during the 1970s and 1980s, and then stabilized during the 1990s. Use of groundwater for irrigation now averages approximately 6,000 acre-feet each year.

Municipal and industrial use has increased during the 1990s and now averages approximately 12,000 acre-feet per year. Groundwater use by the municipal and industrial sector now comprises the majority of groundwater use in the AMA. Approximately 60 percent of the demand for groundwater in the AMA is now dedicated to municipal and industrial uses, compared to 20 to 25 percent of the demand for that sector in the 1970s. In addition, significant amounts of groundwater have been allocated to approved, but not yet constructed, subdivisions.

2.5.3 Water Level Measurements

Water level measurements from certain wells in the Prescott AMA are available for many years. Some measurements are available as early as the 1930s and 1940s. Personnel from the University of Arizona, the United States Geological Survey, and more recently, the Department have all conducted regular measurements of water levels in the AMA. In 1995, the Department undertook and implemented a program to improve existing water monitoring programs in the Prescott AMA. Figure 2-1 shows index wells and monitoring gages in place in 1995 and Figure 2-2 shows the expanded network of 57 index wells and 5 surface water monitoring gages in place in 1997 as well as proposed stream gages for increased surface water monitoring and 5 new index wells. This network provides representative data from wells of varying depths in both the Upper Alluvial and Lower Volcanic Units, as well as measurements of surface water flows throughout both subbasins in the AMA.

The Department has examined available water level data for the Prescott AMA for both short-term (1994-98) and long-term trends (1940-94). Currently, all trends indicate gradual but definite on-going water level declines in 73 to 75 percent of wells measured. The following discussion focuses first on water level changes from the 1940s until the early 1980s and references a generalized composite water level change map (Figure 2-6). Second, the water level changes since 1982 and during the last 5 years are discussed and illustrated with maps showing actual changes at measured wells in Figures 2-7 and 2-10.

Figure 2-6 illustrates water level declines in excess of 75 feet in the northern portion of the Little Chino Subbasin and highly localized declines of over 100 feet in the Prescott Valley well field area in the north-west Upper Agua Fria Subbasin. Lesser widespread declines occurred throughout the Little Chino Subbasin and much of the Upper Agua Fria Subbasin. The wide-spread historic declines throughout most of the Little Chino and the northern portion of the Upper Agua Fria Subbasins illustrate that pumping in the northwestern portion of the Little Chino Subbasin has impacted distant areas of the regional aquifer where little or no historic pumpage occurred. Figure 2-6 also shows one very small area of a 50-foot water level rise in the center of the map. This rise is caused by the City of Prescott's effluent recharge project at the airport. These water level changes are discussed in greater detail below.

Between 1940 and 1960, agricultural pumpage had caused water level declines in both the Upper Alluvial Unit and Lower Volcanic Unit aquifers throughout most of the Little Chino Subbasin. Water level declines in excess of 40 feet were noted in much of the confined area of the Lower Volcanic Unit aquifer. However, in the agricultural area of the Little Chino Subbasin, water levels remained constant or rose in the shallow Upper Alluvial Unit aquifer. In this area, "perched" water levels developed due to the presence of intervening, fine-grained layers which substantially restricted the downward flow of excess irrigation water.

Water level declines were probably minimal in the Upper Agua Fria Subbasin during the 1940 through 1960 period due to limited groundwater pumping activity. Farming and ranching operations began in the Upper Agua Fria Subbasin in the mid 1930s; however, the amount of acreage farmed was small (Wigal, 1988). Groundwater pumping for agricultural irrigation in the Upper Agua Fria Subbasin did not become significant until the 1960s. Additionally, municipal groundwater pumping was very small in the Upper Agua Fria Subbasin until the late 1970s (Corkhill and Mason, 1995).

From 1961 to the early 1980s, water levels declined rapidly in much of the Prescott AMA due to a period of heightened agricultural activity. By 1981, groundwater pumpage in the Little Chino Subbasin had caused water level declines of about 70 to 80 feet from predevelopment levels in the confined zone of the Lower Volcanic Unit. In the Lonesome Valley area, water levels declined by 40 to 60 feet from predevelopment levels. By the end of the 1970s, water levels in the "perched" area of the Little Chino Subbasin had also begun to decline due to an increase of shallow domestic well pumpage. As illustrated by Figure 2-8, by 1981, groundwater pumpage in the Upper Agua Fria Subbasin had created a localized cone of depression in the Prescott Valley area. Groundwater discharge as baseflow on the Agua Fria River near Humboldt was reduced from predevelopment levels of approximately 2,000 acre-feet per year to about 1,100 acre-feet per year (Corkhill and Mason, 1995).

The rate of water level declines slowed in the Little Chino Subbasin in the early 1980s, and water levels stabilized in some wells. Although the declines in the water levels slowed significantly, they continued from the early 1980s to 1998 in most areas of the AMA. Figure 2-7 illustrates the actual water level changes over the last 16 years at individual wells measured in both 1982 and 1998. In the northwestern portion of the Little Chino Subbasin, where agricultural activity was greatest, water level declines generally ranged between 5 and 20 feet in the Lower Volcanic Unit aquifer between 1982 and 1998, due to agricultural and municipal pumping activity. Water levels also declined by as much as 40 feet in the "perched" Upper Alluvial Unit aquifer over this same period in the Little Chino Subbasin. This trend was attributable to increased domestic well pumpage and reduced agricultural incidental recharge. In the west-central section of the Little Chino Subbasin, water levels rose slightly or remained stable. Water levels in the west-central area have been stable for a number of years. This indicates that wells in this portion of the AMA are likely hydrologically isolated from the regional aquifer (Schwalen, 1967).

Additional water level declines occurred in some wells between 1982 and 1998 in the Prescott Valley area of the Upper Agua Fria Subbasin. Water levels were generally stable in the Upper Alluvial Unit aquifer in the Dewey-Humboldt area in the Upper Agua Fria Subbasin, where fluctuations were less than five feet.

From 1982 to 1998, water levels also rose in some wells in the Prescott Valley area and along Lynx Creek in the Upper Agua Fria Subbasin. It should be noted, however, that the areas of water level rise were generally located near major surface water drainages and were not in the vicinity of the well field serving Prescott Valley. It is the Department's opinion that increased recharge from flood flows partially accounts for the rises in these areas.

Over the past five years, water level measurements were collected from 57 index wells within the Prescott AMA. Figure 2-10 illustrates the actual water level changes over the last five years at individual wells measured in both 1994 and 1998. Water level declines from 1994-1998 were observed in the agricultural area of the Little Chino Subbasin, along the Agua Fria River in proximity to the Town of Prescott Valley and its confluence with Lynx Creek, and to the northeast in Lonesome Valley. Declines were also observed at index wells located in or immediately adjacent to hardrock areas. Water level rises were observed at eight index wells during this period, ranging from one to six feet. Water level rises were situated to the east of the Agua Fria River and in the vicinity of Dewey and Humboldt. Other water level rises were confined to sparsely populated portions of the AMA which are characterized by very limited water use. Four index wells revealed no change in water levels.

Generally, the magnitude and direction of water level changes which occurred during the period from 1994 through 1998 were typical of the long-term downward trends. However, the rates of water level change have increased during the last five years.

The slightly higher rates of water level decline for the last four years correlates to a recent period of below average annual precipitation and increasing annual groundwater overdraft pumping. However, the water level data from both periods indicate that a clear majority of measured wells have experienced water level declines, even during times of above average annual precipitation and groundwater recharge (1982-1993). Therefore, it is reasonable to conclude that the recent water level change data adequately reflect the long-term regional trends.

A significant majority of water level monitoring locations in the Prescott AMA demonstrate short-term and long-term declines in water levels. Given the recent population growth and commitments of over 10,000 acre-feet of groundwater to already approved but not yet built development in the Prescott AMA, it cannot reasonably be expected that these trends in declining water levels will be reversed. Additional groundwater-based development in the AMA can only, over the long-term, exacerbate the current water level declines.

2.5.4 Groundwater Storage Trends

The total volume of groundwater storage in the Prescott AMA is about 3 million acre-feet. A map showing the estimated combined minimum depth of the Upper Alluvial Unit and Lower Volcanic Unit aquifers is displayed in Figure 2-11. Although the combined thickness of both the Upper Alluvial Unit and Lower Volcanic Unit aquifers exceeds 1,000 feet in the central part of the Prescott AMA near the subbasin groundwater divide, the average combined thickness of these aquifers throughout most of the Prescott AMA is estimated to be considerably less.

In the Little Chino Subbasin, the combined minimum thickness of the Upper Alluvial Unit and Lower Volcanic Unit aquifers ranges from 0 feet at the subbasin margins to roughly 1,200 feet in thickness at the approximate southern limit of the Lower Volcanic Unit near the subbasin divide. In the vicinity of Chino Valley, the estimated minimum thickness varies from 400 to 600 feet. This vertical extent increases around the Lonesome Valley area from depths of 600 to 1,000 feet. The combined thickness of the Upper Alluvial Unit and Lower Volcanic Unit is estimated to be less than 200 feet at the basin margins. Consequently, although the central and southeastern portions of the Little Chino Subbasin have considerable aquifer thickness, the remaining areas have significantly smaller aquifer thickness and correspondingly less groundwater storage capacity. This is particularly relevant when considering that the majority of groundwater pumping in the Little Chino Subbasin occurs near Chino Valley where the combined aquifer thickness ranges from about 200 to 700 feet in thickness.

In the Upper Agua Fria Subbasin, the Upper Alluvial Unit aquifer thickness varies from 800-1,200 feet in the vicinity of Prescott Valley, to roughly 200-400 feet near Dewey and Humboldt. The saturated areal extent of the aquifer in the Upper Agua Fria Subbasin is more restricted than in the Little Chino Subbasin.

2.6 GROUNDWATER QUALITY LIMITATIONS ON SUPPLY

Naturally occurring radon has caused the closure of some domestic wells which produce groundwater from granitic aquifers. These instances are primarily confined to individual dry lots located along the mountain front regions of the Prescott AMA. The Environmental Protection Agency (EPA) is currently in the process of developing a Maximum Contaminant Level (MCL) standard for radon, which could produce more domestic well closures. Since radon is a naturally occurring substance within the granitic formations, a remedial response is not possible. Although no major groundwater well fields are threatened by radon exposure, the proliferation of dry lot developments in threatened areas may be impacted to some extent by the adoption of a radon MCL.

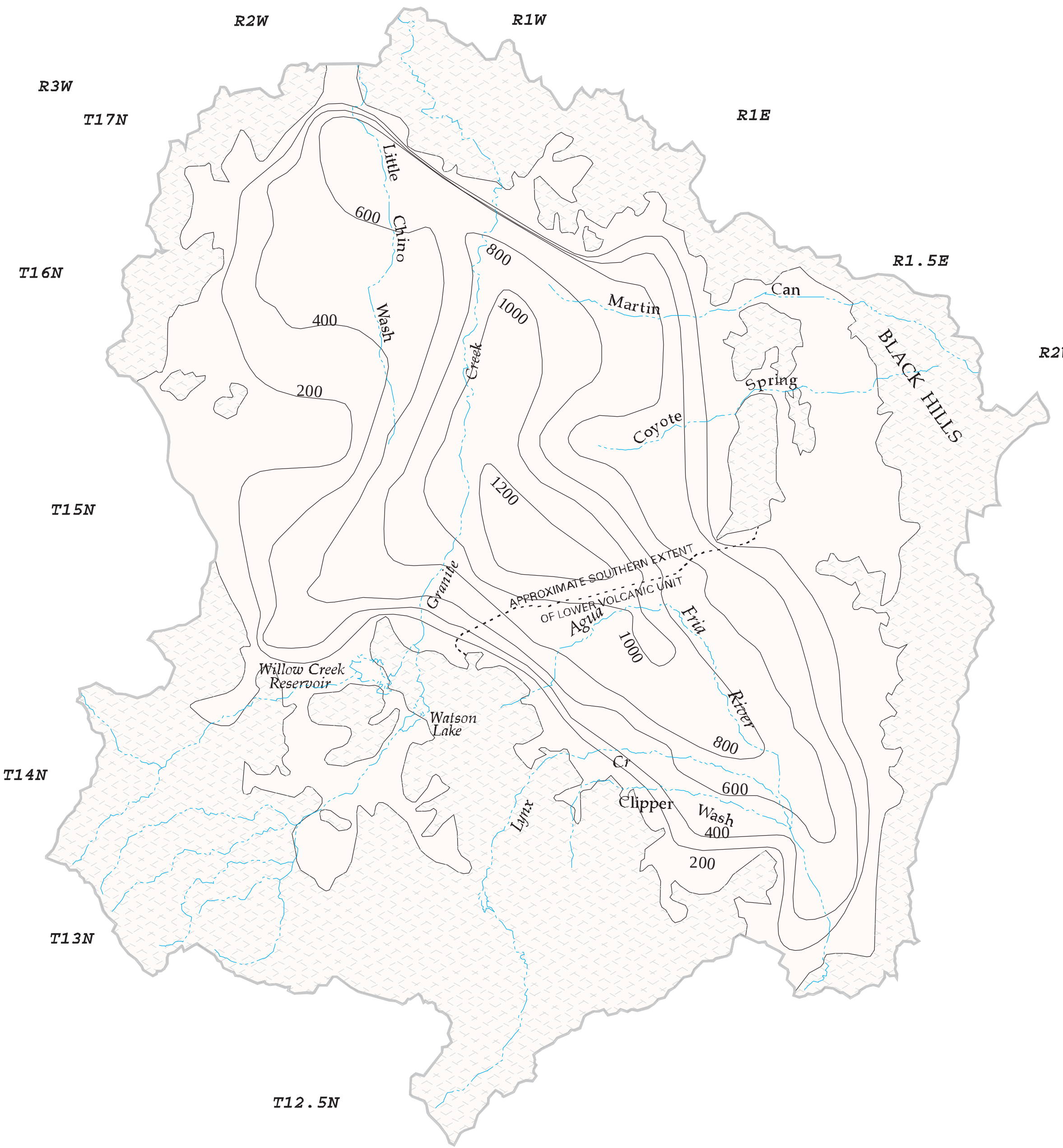
Another potential limitation stems from the presence of a large number of septic systems within the Prescott AMA. Areas with a concentration of individual septic systems which overlap areas of groundwater pumpage could pose a health hazard where the depth to water is relatively shallow. Again, this is a problem often associated with domestic wells.

2.7 AVAILABILITY AND UTILIZATION OF RENEWABLE SUPPLIES

2.7.1 Introduction

It has become clear, since promulgation of the Second Management Plan, that utilization of Central Arizona Project (CAP) water is not economically feasible in the Prescott AMA due to the distance of the AMA's water users from the aqueduct. Recognizing this limitation, the City of Prescott and the Yavapai-Prescott Indian Tribe have transferred their CAP allocations to the City of Scottsdale. The proceeds from these transfers are being used to develop alternative water supplies.

In an effort to secure sources of long-term and renewable water, the Prescott AMA community has pursued a number of options including: (1) the purchase of CVID surface water rights, (2) the expanded use of effluent for turf irrigation, (3) effluent recharge for storage and recovery credits, and (4) studies exploring the potential for cloud seeding as a viable water augmentation program for northern and central Arizona.



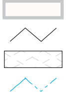
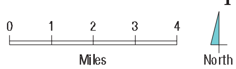


Figure 2 - 11

Depths of Upper Alluvial Unit
and Lower Volcanic Unit Aquifers



ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

Other potential options may include the importation of groundwater from the Big Chino Subbasin and assistance from the newly created Arizona Water Banking Authority (AWBA).

2.7.2 Renewable Supply Use Trends

2.7.2.1 Purchase of CVID Water Rights

The City of Prescott purchased the Chino Valley Irrigation District's rights to surface water impounded at Watson Lake and Willow Creek reservoirs. Under this agreement, the City of Prescott acquired ownership of the dams, the reservoirs, and through a sever and transfer action facilitated by the Department, acquired the storage rights on approximately 11,000 acre-feet annually of surface water flows. The City will maintain the lakes for recreational uses and will release approximately 1,500 acre-feet per year for recharge at their recharge facility. Most of those CVID surface right holders also extinguished those groundwater rights to the City of Prescott in exchange for a 100 year assured water supply to develop their lands.

Under the agreement with CVID, the City of Prescott will make available 1,500 acre-feet of recovered effluent annually to those CVID members who are planning to continue irrigating. The agreement also allows an additional 1,400 acre-feet of groundwater to be pumped as IGFR water. The City has also agreed to make available another 500 acre-feet of recovered effluent if the demand exists. The priority of water use will be: (1) the 1,500 acre-feet of recovered effluent, (2) the approximately 1,400 acre-feet of groundwater, and (3) the additional 500 acre-feet of recovered effluent. Following 2005, IGFR usage will be limited to 25 percent of the face value of each groundwater allocation.

Effluent recovery wells will be a district responsibility. The Department estimates that nearly all of the CVID land will be phased out of production by year 2005.

2.7.2.2 Effluent Use

The January 1999 declaration that the Prescott AMA is not at safe-yield and the related requirements that new subdivisions be served with alternative water supplies will increase the need to utilize effluent resources. Renewable resource utilization activities within the Prescott AMA have primarily been pursued by the City of Prescott, which actively encourages the use of treated effluent to irrigate turf-related facilities. The City has a policy that requires all new turf facilities with greater than 100 acre-feet of annual demand to use effluent provided by the City. The City currently treats effluent at the Sun Dog Wastewater Treatment Plant. The plant delivers about 1,000 acre-feet of effluent annually to the Antelope Hills Golf Course, comprised of two 18-hole courses, located within its service area.

The City of Prescott has an annual commitment to deliver 300 acre-feet of effluent to the CVID. However, in drought years the delivery of this supply is not possible due to lack of sufficient flow in the CVID canal system. There is some potential for additional effluent to be used on certain crops for agricultural irrigation. The effluent would need to be made affordable to farmers before they would switch from groundwater to effluent as a source of supply. The City has also applied for a recovery permit which would allow the recovery of effluent for use at selected industrial and turf facilities.

2.7.2.3 Effluent Recharge

The City of Prescott currently has an Underground Storage Facility (USF) permit (71-519567) which allows recharge of up to 6,721 acre-feet of effluent annually from the Sun Dog Wastewater Treatment Plant into percolation ponds near the Prescott Airport. The City also has two Water Storage permits. Permit number 73-519567 is designated as non-recoverable, allowing no credits to be earned, while permit number 73-528737 allows 6,721 acre-feet of recoverable credits annually.

The Department annually determines the total volume of effluent credits accrued since the issuance of the permits. These permits expire July 8, 2008.

Recovery of the stored water is allowed pursuant to a recovery well permit and may not exceed the per annum volume specified in the storage permit. In order to recover recharged water from a well through stored credits, a municipal provider must first obtain a recovery well permit from the Department.

Prescott Valley has an Underground Storage Facility permit (71-566417) and a Water Storage permit (73-566417), which allows 800 acre-feet of effluent to be recharged over a two year period. Under this project, Prescott Valley would ascertain the hydrologic impact of effluent recharge and assess the storage potential of the underlying aquifer. If successful, it would likely be the beginning of a larger recharge project designed to meet future water demands in the vicinity.

2.7.2.4 Big Chino Groundwater Importation

Although the withdrawal and transportation of groundwater across subbasins was generally prohibited by the Groundwater Transportation Act (A.R.S. § 45-551), there are statutory exceptions to the prohibition, both contained in A.R.S. § 45-555. One exception is available to any city or town in the Prescott AMA. It allows a city or town owning (or controlling by owner's consent) retired, historically irrigated acres overlying the Big Chino Subbasin to withdraw and transport up to 3 acre-feet per retired acre per year of Big Chino groundwater into the AMA.

A second exception, A.R.S. § 45-555(E), is available only to the City of Prescott. It allows the City to withdraw and transport to the AMA up to 14,000 acre-feet per year from the Big Chino Subbasin to the extent that the groundwater replaces CAP allocations in the AMA or Verde River groundwater basin, or facilitates certain Indian water rights settlements. The Department estimates that the City of Prescott currently qualifies under this exception for up to 8,717 acre-feet per year from the Big Chino Subbasin.

Although the City of Prescott has no plans to import groundwater, they have purchased land in the Big Chino Subbasin on which they could construct a well field for this purpose and have evaluated the costs to construct a pipeline between this well-field and its existing municipal wells near Chino Valley. If a city or town, including the City of Prescott, chooses to purchase additional historically irrigated lands in the Big Chino Subbasin, then additional volumes of groundwater may be withdrawn and transported into the Prescott AMA pursuant to the first exception noted above.

2.7.2.5 The Arizona Water Banking Authority

In 1996, the State Legislature created the AWBA to maximize the long-term benefit of Arizona's 2.8 million acre-foot share of the Colorado River. Each year, the AWBA will pay the delivery and storage costs to bring the state's unused Colorado River water into central and southern Arizona via the CAP, where it will be stored underground in existing aquifers or be used directly by irrigation districts in lieu of pumping groundwater. For each acre-foot stored, the AWBA accrues a credit that can be redeemed in the future when Arizona's communities need this back-up water supply. Identified uses include: drought protection, enhanced water management, Indian water rights settlements, statewide benefit, and interstate water transfers.

Although the AWBA was principally designed to assist water users within the CAP delivery area of which the Prescott AMA is not a part, some benefit may be derived in the future through water exchanges between upstream Verde River water users associated with the Salt River Project (SRP) and downstream CAP contract holders in the Phoenix metropolitan area.

REFERENCES

Arizona Department of Water Resources, 1994. *Arizona Water Resources Assessment, Volume 1: Inventory and Analysis (Prescott Active Management Area).*

Arizona Department of Water Resources, 1997. *Index Well Measurement and Water Level Data from Basic Data Section for Prescott Active Management Area.* Compiled and Summarized By F. Corkhill, Hydrology Division.

Corkhill, E.F. and Mason, D.A., 1995. *Hydrogeology and Simulation of Groundwater Flow, Prescott Active Management Area, Yavapai County, Arizona.* Arizona Department of Water Resources Modeling Report No. 9, 143 p.

Knauth, P.L. and M. Greenbie, 1997. *Stable Isotope Investigation of Groundwater - Surface Water Interactions in the Verde River Headwaters Area.* Department of Geology, Arizona State University.

National Weather Service Historical Precipitation Records. Prescott and Chino Valley, Arizona gages.

Oppenheimer, J.M. and J.S. Sumner, 1980. Depth-to-bedrock map (Prescott). Lab of Geophysics, University of Arizona.

Remick, W.H., 1983. Maps Showing Groundwater Conditions in the Prescott Active Management Area, Yavapai County, Arizona. 1982 Arizona Department of Water Resources Maps Series Report No. 9.

Schwalen, H.C., 1967. *Little Chino Valley Artesian Area and Groundwater Basin, Technical Bulletin 178*, Agricultural Experiment Station, University of Arizona, Tucson, Arizona.

Wellendorf, W., 1994. Personal Communication with F. Corkhill (Arizona Department of Water Resources) Concerning Well Discharge and Specific Capacity of a Recently Drilled Offset Well to Shamrock Water Company's "Santa Fe" Well.

Wigal, D.V., 1988. *Adequacy Report for Shamrock Water Company.*

Wilson, R.P., 1988. *Water Resources of the Northern Part of the Agua Fria Area, Yavapai County, Arizona.* Arizona Department Of Water Resources Bulletin No. 5.